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Luthra

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(54) **METHOD OF ENCODING VIDEO CONTENT**

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(51) **Int. Cl.**

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H04N 7/26	(2006.01)
H04N 13/02	(2006.01)
H04N 21/434	(2011.01)
H04N 21/2365	(2011.01)
H04N 19/597	(2014.01)
H04N 19/46	(2014.01)
H04N 19/61	(2014.01)
H04N 19/86	(2014.01)
H04N 19/70	(2014.01)

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CPC ***H04N 21/4347*** (2013.01); ***H04N 19/46*** (2014.11); ***H04N 19/597*** (2014.11); ***H04N 19/61*** (2014.11); ***H04N 19/86*** (2014.11); ***H04N 21/2365*** (2013.01); *H04N 19/117* (2014.11); *H04N 19/174* (2014.11); *H04N 19/70* (2014.11)

(58) **Field of Classification Search**

CPC H04N 7/50; H04N 7/26941; H04N 21/2365; H04N 21/4347; H04N 21/23608
USPC 375/240.01, 240.26; 348/42, 51
See application file for complete search history.

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Primary Examiner — Jamie Atala
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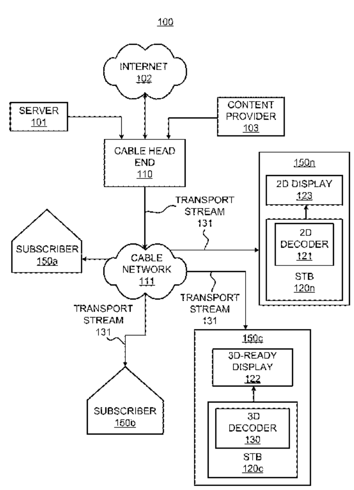
(57) **ABSTRACT**

In a method of encoding video content, bits of a first view and a second view of a three-dimensional (3D) video content are manipulated to occupy a first slice of video and a second slice of video, wherein a boundary is configured to be formed between the first and second slices. In addition, the bits of each of the first slice and the second slice are encoded separately from each other to form a first independently compressed video slice and a second independently compressed video slice. The first and second independently compressed video slices are then multiplexed to form at least one transport stream operable to be processed to render at least one of two-dimensional (2D) and 3D video.

21 Claims, 8 Drawing Sheets



(51) **Int. Cl.**
H04N 19/117 (2014.01)
H04N 19/174 (2014.01)

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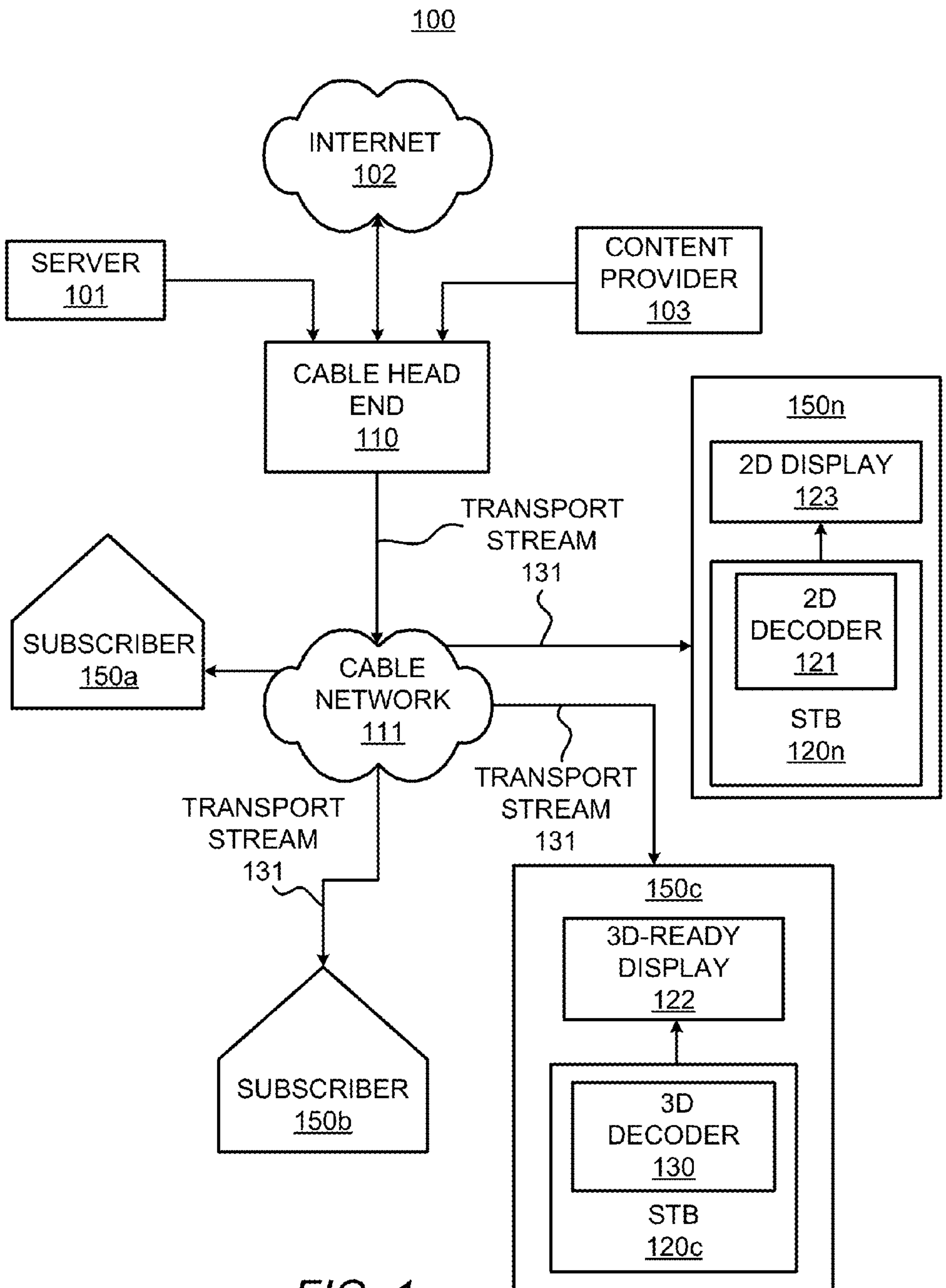
100
INTERNET
102
SERVER
101
CONTENT
PROVIDER
103
CABLE HEAD
END
110
TRANSPORT
STREAM
131
150n
2D DISPLAY
123
2D
DECODER
121
STB
120n
SUBSCRIBER
150a
CABLE
NETWORK
111
TRANSPORT
STREAM
131
TRANSPORT
STREAM
131
150c
3D-READY
DISPLAY
122
3D
DECODER
130
STB
120c
SUBSCRIBER
150b

FIG. 1

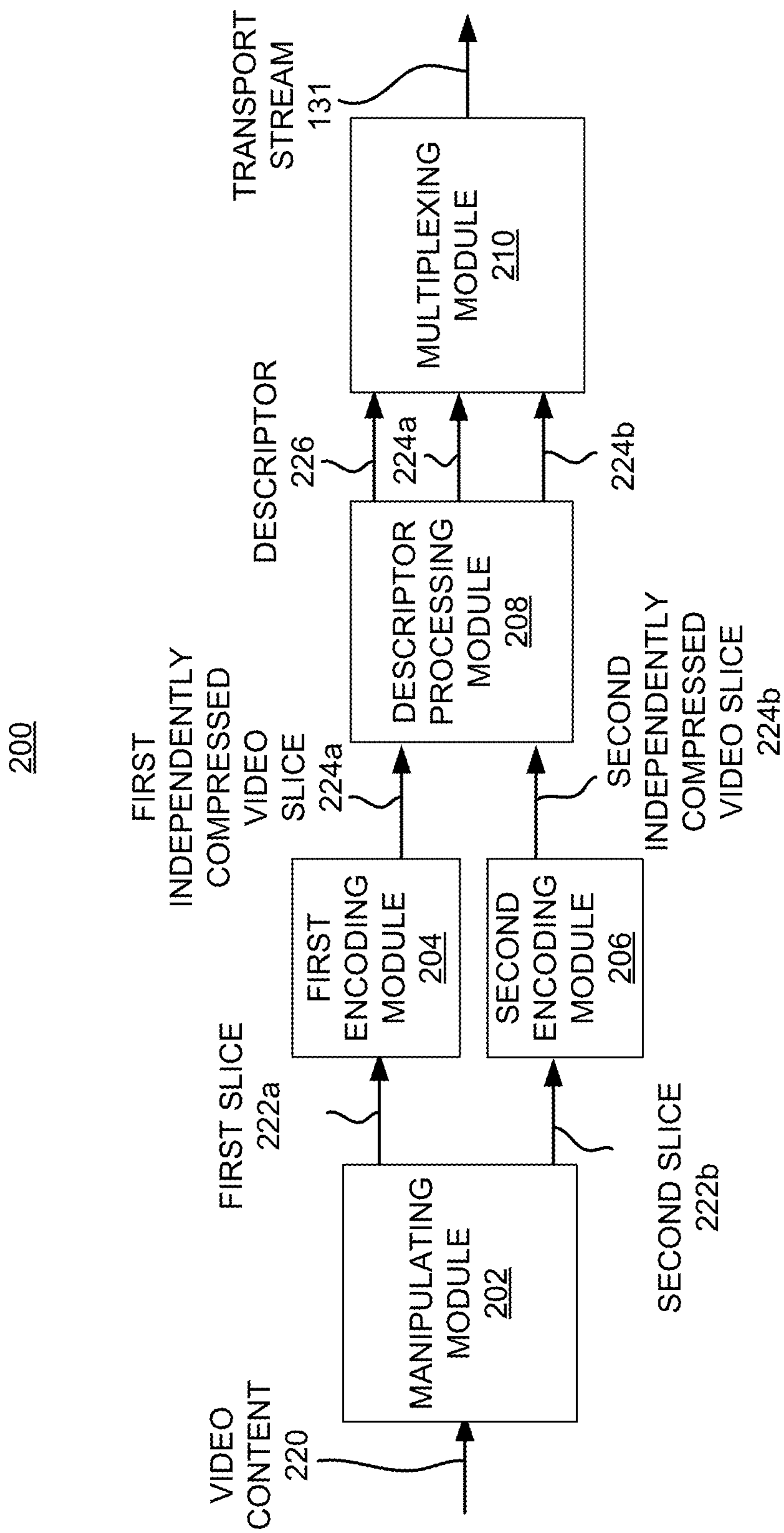
200
VIDEO CONTENT 220
MANIPULATING MODULE 202
FIRST SLICE 222a
SECOND SLICE 222b
FIRST ENCODING MODULE 204
SECOND ENCODING MODULE 206
FIRST INDEPENDENTLY COMPRESSED VIDEO SLICE 224a
SECOND INDEPENDENTLY COMPRESSED VIDEO SLICE 224b
DESCRIPTOR PROCESSING MODULE 208
DESCRIPTOR 226
224a
224b
MULTIPLEXING MODULE 210
TRANSPORT STREAM 131

FIG. 2

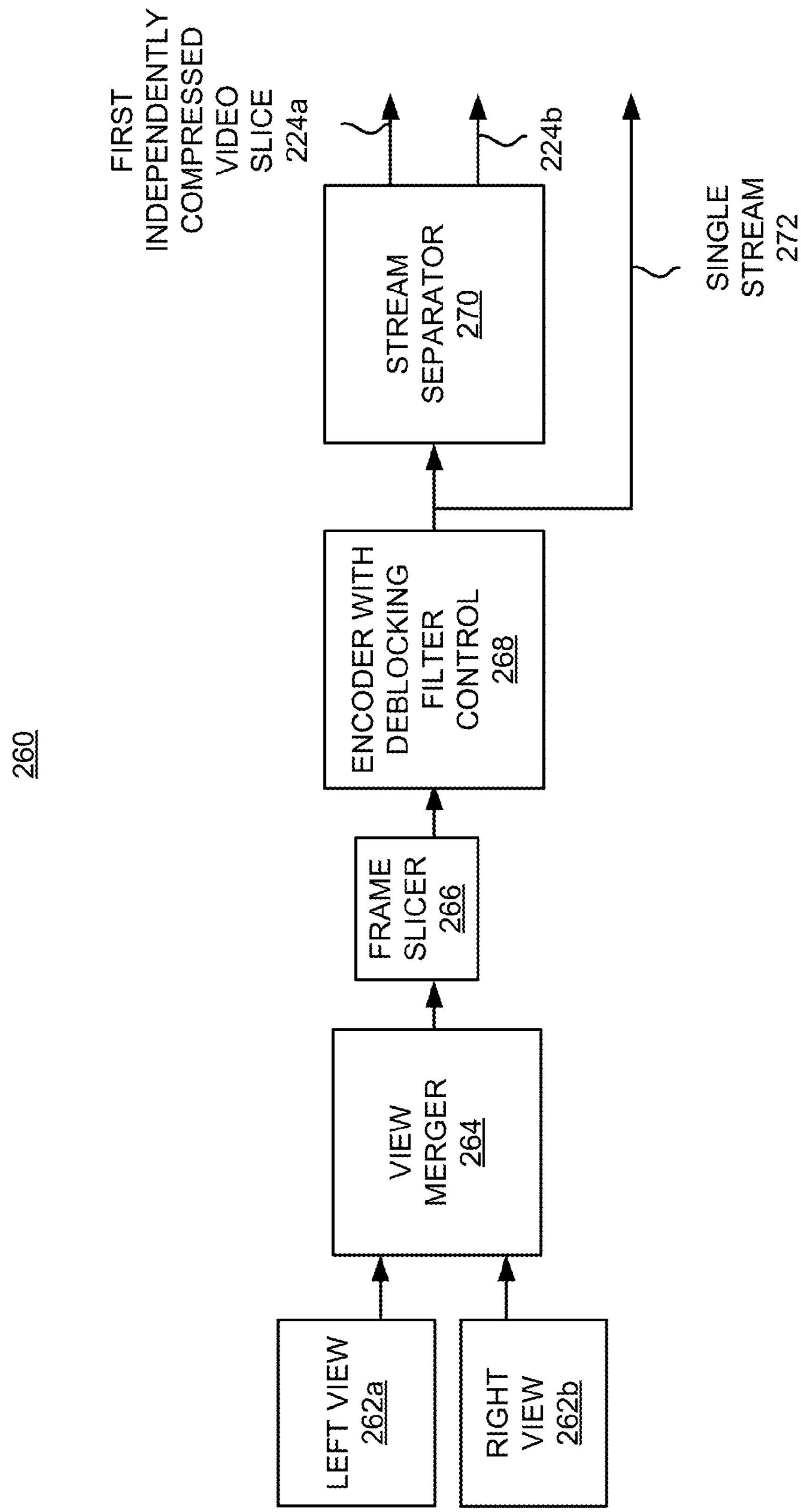
260
LEFT VIEW 262a
RIGHT VIEW 262b
VIEW MERGER 264
FRAME SLICER 266
ENCODER WITH DEBLOCKING FILTER CONTROL 268
STREAM SEPARATOR 270
FIRST INDEPENDENTLY COMPRESSED VIDEO SLICE 224a
224b
SINGLE STREAM 272

FIG. 3

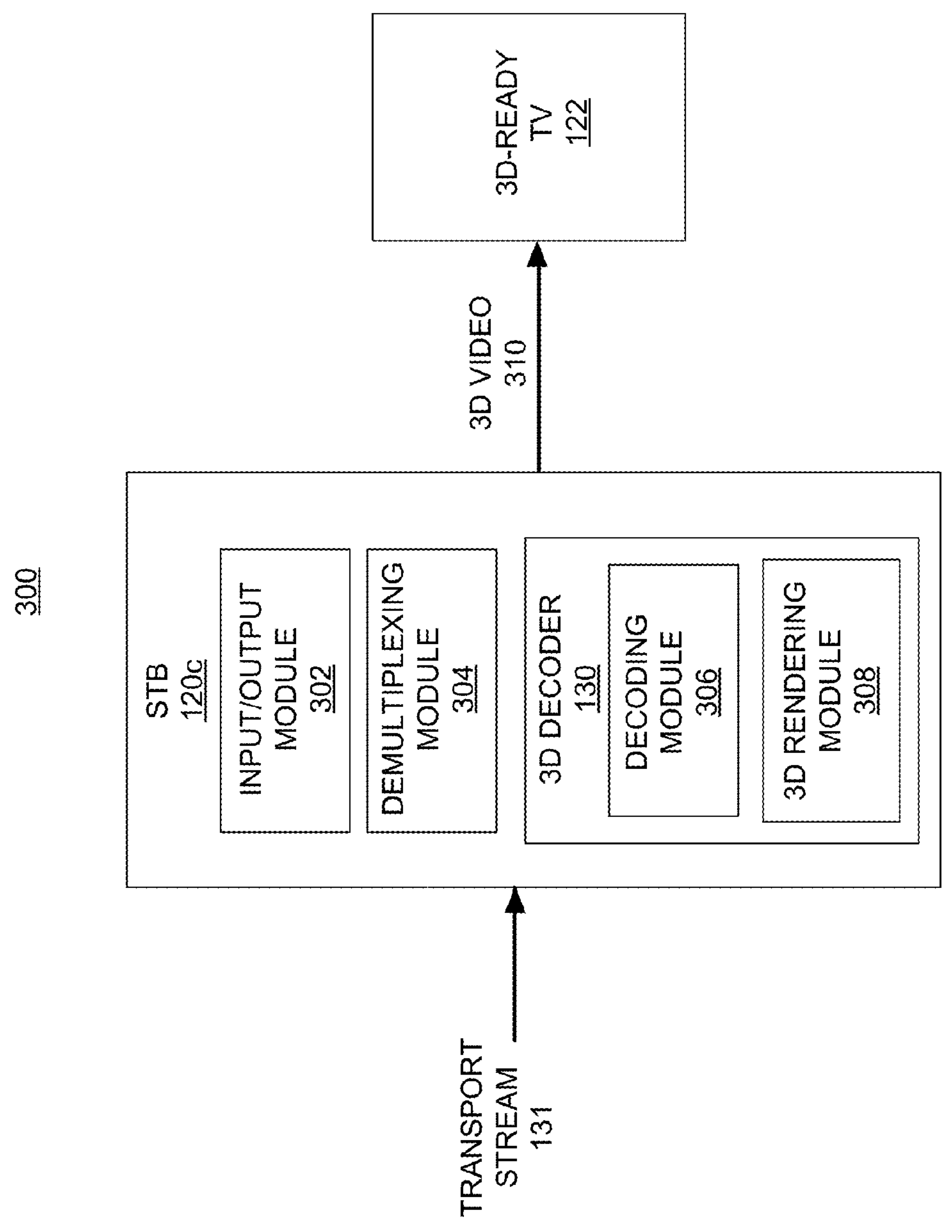
300
STB
120c
INPUT/OUTPUT
MODULE
302
DEMULTIPLEXING
MODULE
304
3D DECODER
130
DECODING
MODULE
306
3D RENDERING
MODULE
308
3D VIDEO
310
3D-READY
TV
122
TRANSPORT
STREAM
131

FIG. 4

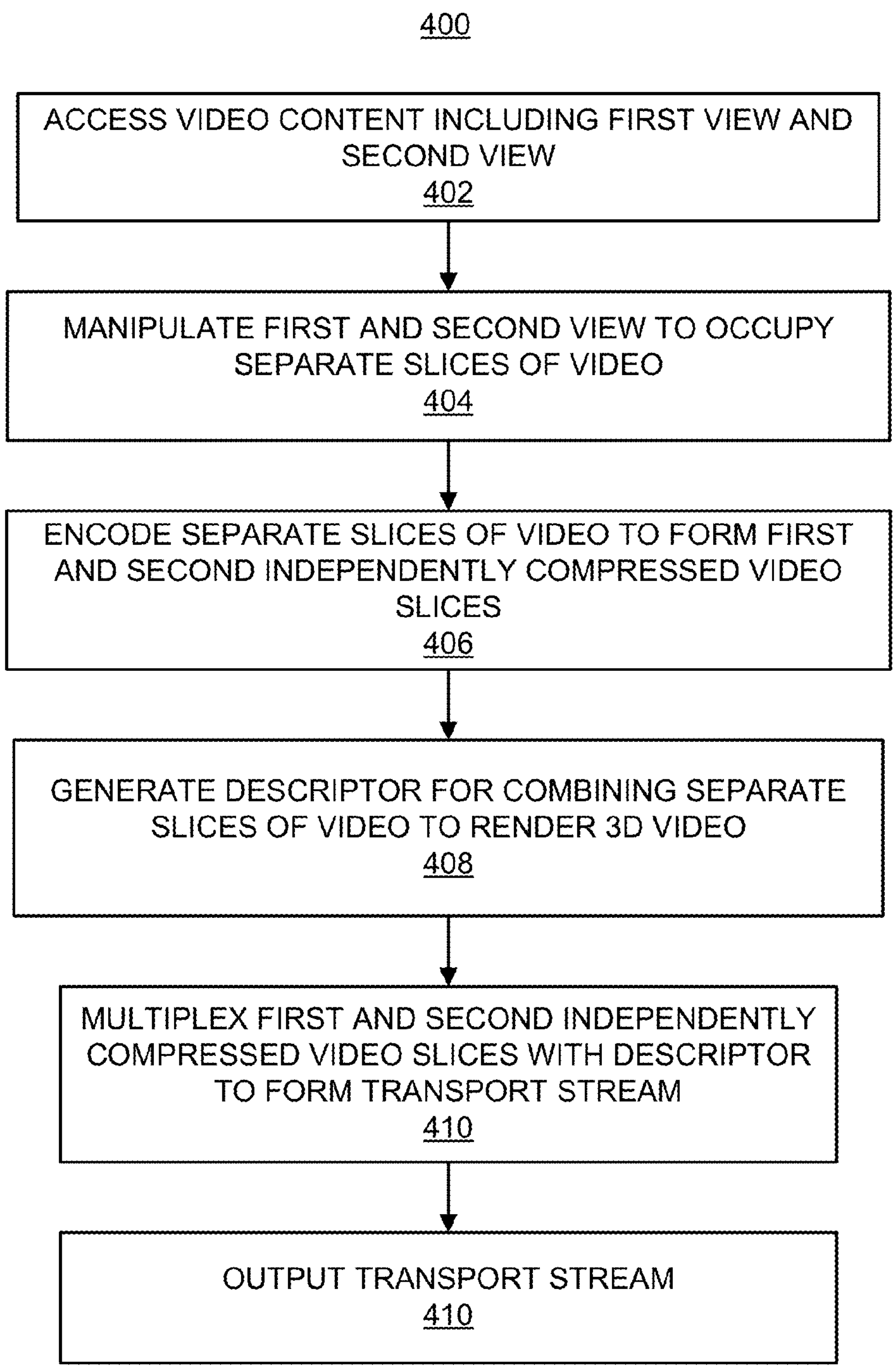
400
ACCESS VIDEO CONTENT INCLUDING FIRST VIEW AND SECOND VIEW
402
MANIPULATE FIRST AND SECOND VIEW TO OCCUPY SEPARATE SLICES OF VIDEO
404
ENCODE SEPARATE SLICES OF VIDEO TO FORM FIRST AND SECOND INDEPENDENTLY COMPRESSED VIDEO SLICES
406
GENERATE DESCRIPTOR FOR COMBINING SEPARATE SLICES OF VIDEO TO RENDER 3D VIDEO
408
MULTIPLEX FIRST AND SECOND INDEPENDENTLY COMPRESSED VIDEO SLICES WITH DESCRIPTOR TO FORM TRANSPORT STREAM
410
OUTPUT TRANSPORT STREAM
410

FIG. 5

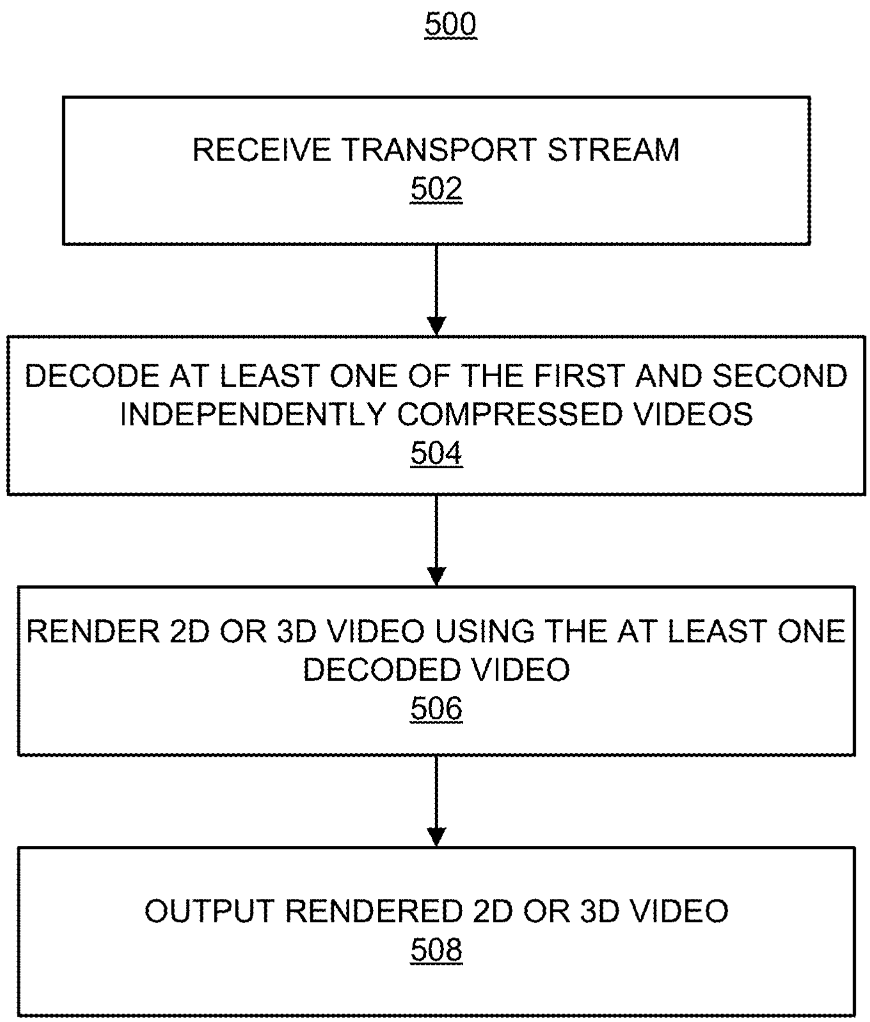
500
RECEIVE TRANSPORT STREAM
502
DECODE AT LEAST ONE OF THE FIRST AND SECOND INDEPENDENTLY COMPRESSED VIDEOS
504
RENDER 2D OR 3D VIDEO USING THE AT LEAST ONE DECODED VIDEO
506
OUTPUT RENDERED 2D OR 3D VIDEO
508

FIG. 6

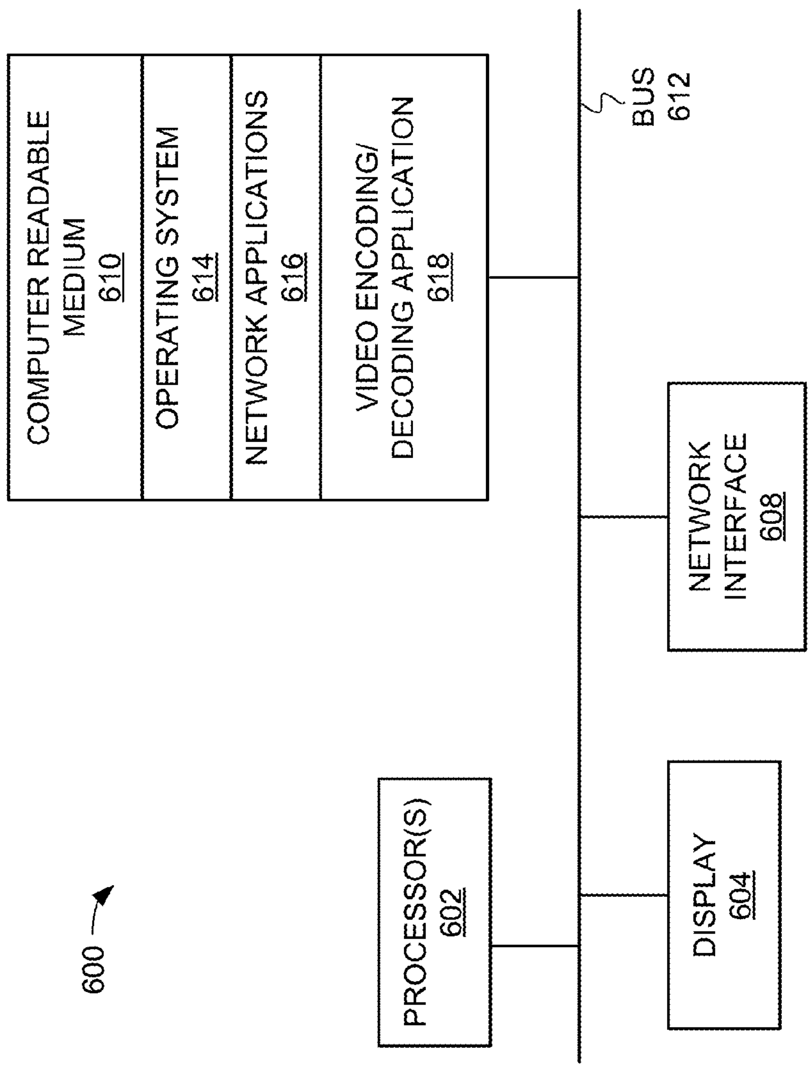
600
COMPUTER READABLE MEDIUM
610
OPERATING SYSTEM
614
NETWORK APPLICATIONS
616
VIDEO ENCODING/ DECODING APPLICATION
618
BUS
612
PROCESSOR(S)
602
DISPLAY
604
NETWORK INTERFACE
608

FIG. 7

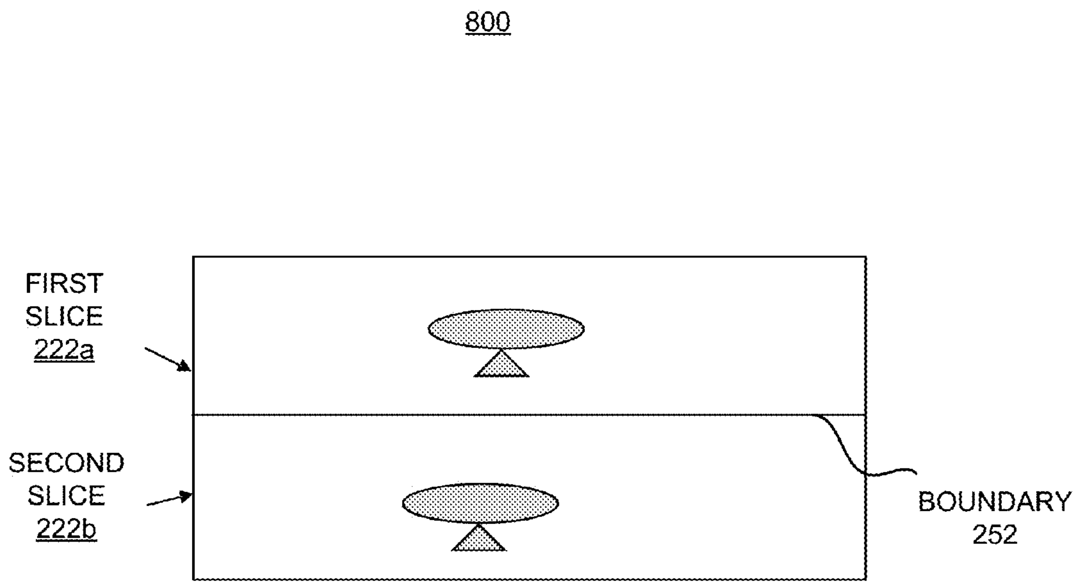

FIG. 8

METHOD OF ENCODING VIDEO CONTENT

CLAIM OF PRIORITY

The present application claims the benefit of priority to U.S. Provisional Patent Application Ser. No. 61/230,780, filed on Aug. 3, 2009, entitled "Backward Compatible 3D TV Format and Method", the disclosure of which is hereby incorporated by reference in its entirety.

BACKGROUND

Depth perception for a three dimensional television (3D TV) is provided by capturing two views, one for the left eye and other for the right eye. These two views are compressed and sent over various networks or stored on storage media. A decoder decodes the two views and sends the decoded video to the 3D TV for display. The two views are known to be either merged into a single video frame or kept separate.

A known benefit of merging the two views in a single video frame is that current encoders and decoders can be used to compress and decompress the video. However, this approach creates two problems. First, video compression algorithms, such as MPEG-4 AVC based compression algorithms, cause cross talk between the two views at their edges. One approach currently used to avoid cross talk between the two eye views is to turn off the deblocking filter in the AVC/H.264 encoding process. However, this approach is known to reduce coding efficiency and creates blocking artifacts in the video. A second problem with merging the two views in a single video frame is that the merged video is not backward compatible with two dimensional (2D) TVs, that is, current 2D TVs cannot display the decoded video corresponding to one of the two views.

SUMMARY

According to an embodiment, a method of encoding video content is disclosed. The method includes manipulating bits of a first view and a second view of a three-dimensional (3D) video content to occupy a first slice of video and a second slice of video. A boundary is configured to be formed between the first and second slices. Each of the bits of first slice and the second slice is encoded separately from each other to form a first independently compressed video slice and a second independently compressed video slice. Thereafter, the first and second independently compressed video slices are multiplexed to form at least one transport stream operable to be processed to render at least one of the two-dimensional (2D) and the 3D video.

According to another embodiment, a video encoder is operable to encode video content. The video encoder includes one or more modules configured to manipulate bits of a first view and a second view of a three-dimensional (3D) video content to occupy a first slice of video and a second slice of video. A boundary is configured to be formed between the first and second slices. The one or more modules are also configured to encode the bits of each of the first and the second slices separately from each other to form a first independently compressed video slice and a second independently compressed video slice, and to multiplex the first independently compressed video slice and the second independently compressed video slice to form at least one transport stream which is operable to be processed to render at least one of the 2D and the 3D video. The video encoder also includes a processor configured to implement the one or more modules.

According to another embodiment, a method of rendering at least one transport stream into a displayable video is disclosed. The method includes receiving the at least one transport stream, which includes a first independently compressed video slice corresponding to a first view of a three-dimensional (3D) video and a second independently compressed video slice corresponding to a second view of the 3D video. The first and second independently compressed video views are configured to occupy separate slices of video. A boundary is configured to be formed between the first and second slices. The bits of at least one of the first and second independently compressed video slices are then decoded. One of a 2D and a 3D video are rendered using the at least one decoded first and second independently compressed video slices.

According to another embodiment, a video decoder includes one or more modules configured to receive at least one transport stream including a first independently compressed slice corresponding to a first view of a 3D video and a second independently compressed video slice corresponding to a second view of the 3D video. The first and second views are configured to occupy separate slices of video. A boundary is configured to be formed between the first and second slices. The one or more modules are further configured to decode bits of at least one of the first and second independently compressed video slices and to render one of a 2D and a 3D video using the at least one of the first and second independently compressed video slices. The video decoder also includes a processor configured to implement the one or more modules

Still in a further embodiment, a computer readable storage medium on which is embedded one or more computer programs implements the above-disclosed methods of encoding the video content and rendering a transport stream into a displayable video is disclosed.

Embodiments of the present invention provide a method and apparatus for encoding video content to be rendered by a decoder as one of a 2D and a 3D video. The video content includes first and second views that correspond to displays for left and right eyes. When the video content is to be displayed as a 3D video, both the first views and second views are rendered. However, when the video content is to be displayed as a 2D video, such as, when a set-top box is equipped with a 2D decoder, only one of the first view and the second view is rendered. As such, a single transport stream containing both the first view and the second view may be transmitted to set-top boxes having one of a 2D and a 3D decoder. Alternately, multiple transport streams containing the first and second views may be sent with a single one of the multiple transport streams being operable to render 2D video.

BRIEF DESCRIPTION OF THE DRAWINGS

Features of the present invention will become apparent to those skilled in the art from the following description with reference to the figures, in which:

FIG. **1** illustrates a network architecture, according to an embodiment of the invention;

FIG. **2** illustrates a functional block diagram of a 3D video encoder, according to an embodiment of the invention;

FIG. **3** illustrates a functional block diagram of a 3D video encoder, according to another embodiment of the invention;

FIG. **4** illustrates a simplified block diagram of a 3D video decoder, according to an embodiment of the invention;

FIG. **5** illustrates a flow diagram of a method of encoding video content, according to an embodiment of the invention;

FIG. **6** illustrates a flow diagram of a method of rendering a transport stream into a displayable video, according to an embodiment of the invention, according to an embodiment of the invention;

FIG. **7** shows a block diagram of a computer system that may be used in encoding video content in a transport stream and rendering 3D video from the transport stream, according to an embodiment of the invention; and

FIG. **8** illustrates a diagram of slices of video, according to an embodiment of the invention.

DETAILED DESCRIPTION

For simplicity and illustrative purposes, the present invention is described by referring mainly to exemplary embodiments thereof. In the following description, numerous specific details are set forth to provide a thorough understanding of the present invention. However, it will be apparent to one of ordinary skill in the art that the present invention may be practiced without limitation to these specific details. In other instances, well known methods and structures have not been described in detail to avoid unnecessarily obscuring the present invention.

FIG. **1** illustrates a network architecture **100** of a system in which a 3D video decoder **130** may be used, according an embodiment. As shown in FIG. **1**, the network architecture **100** is illustrated as a cable television (CATV) network architecture, including a cable head-end **110** and a cable network **111**. A number of data sources **101**, **102**, **103**, may be communicatively coupled to the cable head-end **110** including, but in no way limited to, a plurality of servers **101**, the Internet **102**, radio signals, or television signals received via a content provider **103**. The cable head-end **110** is also communicatively coupled to one or more subscribers **150*a*-150*n*** through the cable network **111**. It should be understood that the network architecture **100** depicted in FIG. **1** may include additional components and that some of the components described herein may be removed and/or modified without departing from a scope of the network architecture **100**.

The cable head-end **110** is configured to output a transport stream **131** to the subscribers' **150*a*-150*n*** set top boxes (STBs) **120*a*-120*n*** through the cable network **111**, which may include a satellite transmission, the Internet **102** or other network using, for instance, fixed optical fibers or coaxial cables. The STBs **120*a*-120*n*** are devices receive the transport stream **131** from the cable head-end **110** and processes the transport stream **131** to be in a format for display on a television, computer monitor, personal digital assistant (PDA), cellular telephone, etc. According to an embodiment, one or more of the STBs **120*a*-120*n*** comprise standalone devices supplied by a cable or satellite television provider. According to another embodiment, one or more of the STBs **120*a*-120*n*** comprise devices and/or software integrated into one or more of televisions, computers, cellular telephones, PDAs, etc.

Each of the STBs **120*a*-120*n*** is equipped with a 2D decoder **121** and/or a 3D decoder **130**. The 2D decoder **121** is configured to decode 2D content; whereas the 3D decoder **130** is configured to decode 3D content and may also be configured to decode 2D content. In addition, or alternatively, one or more of the STBs **120*a*-120*n*** may be equipped with both a 2D decoder **121** and a 3D decoder **130** to thus be able to decode both types of content. In any regard, the STBs **120*a*-120*n*** are configured to output the decoded content to either a 2D display **123** or a 3D-ready display **122**. In order to display the 3D content, a 3D-ready display **122** is required. As discussed in greater detail herein below, the transport stream **131** is configured to provide cross standard compatibility for both the 3D video decoders **130** and 2D decoders **121**.

FIG. **2** illustrates a functional block diagram of a 3D video encoder **200**, according to an embodiment. The 3D video encoder **200** may form part of or be included in the cable head end **110** depicted in FIG. **1** and may generally be configured to render video for transmission to the subscribers **150*a*-150*n***. It should be understood that the 3D video encoder **200** depicted in FIG. **2** may include additional components and that some of the components described herein may be removed and/or modified without departing from a scope of the 3D video encoder **200**.

As shown in FIG. **2**, the 3D video encoder **200** includes a manipulating module **202**, a first encoding module **204**, a second encoding module **206**, a descriptor processing module **208** and a multiplexing module **210**. The modules **202-210** may comprise software, hardware, or a combination of software and hardware. Thus, in one embodiment, one or more of the modules **202-210** comprise circuit components. In another embodiment, one or more of the modules **202-210** comprise software code stored on a computer readable storage medium, which is executable by a processor.

The manipulating module **202** is configured to access video content **220** to be rendered as 3D video. The video content **220** may be accessed, for instance, by receiving the video content from broadcast programs, Internet Protocol TV (IPTV), switched video (SDV), video on demand (VOD) or other video sources, as shown in FIG. **1**. The video content **220** includes a first view and a second view (not shown) that enable the video content **220** to be displayed in 3D video format. The first view comprises one of a left eye view and right eye view and the second view comprises the other of the left eye view and the right eye view.

The manipulating module **202** is configured to manipulate the first view and the second view to occupy a first slice **222*a*** of video and a second slice **222*b*** of video that may be displayed as slices of video. The manipulating module is also configured to form a boundary between the first and second slices **222*a*-222*b***. The first slice **222*a*** and the second slice **222*b*** may be displayed by a 3D-ready display **122** in one or more of various manners to provide a viewer with a 3D viewing experience. As also discussed below, a 2D decoder **121** may decode either of the first slice **222*a*** and the second slice **222*b*** to display the video content **220** on a 2D display **123**.

An example of a manner in which the first slice **222*a*** and the second slice **222*b*** may be displayed as slices of video **800** is shown in FIG. **8**. As shown in FIG. **8**, the slices of video **800** are horizontally arranged and comprise a top half corresponding to the first view and a bottom half corresponding to the second view. The horizontal arrangement of the slices of video **800** allow a decoder better efficiency in reading the separate slices of video. In addition, the top half and the bottom half of the video **800** is separated by a boundary **252**. The boundary **252** between the two slices **222*a*** and **222*b*** enables the deblocking filter to be turned off across the boundary **252**, while still enabling deblocking filtering to be performed within each of the slices **222*a*-222*b***. As such, cross-talk between the first view **222*a*** and the second view **222*b*** may be avoided. By leaving the deblocking activated within each of the slices **222*a*-222*b***, the coding efficiency is not greatly affected and the noise due to blocking is substantially reduced.

The manipulating module **202** is also configured to output the slices of video **800** to separate encoding modules **204** and **206**. Although two encoding modules **204** and **206** configured to separately encode the slices of video **800**, the 3D video encoder **200** may include any number of encoding modules **204** and **206** without departing from a scope of the invention. In this example, the manipulator **202** may manipulate either or both of the top and bottom halves of the separate slices of video **800** into more than one integer number of slices. As such, the manipulator **202** may manipulate the video content **220** into more than two slices to thus form more than two separate video streams, which may each be encoded separately. In the interest of clarity, the following discussion will be directed to instances in which the video content is arranged in first and second slices **222***a* and **222***b*.

The first encoding module **204** is configured to compress the first slice **222***a* to form a first independently compressed video slice **224***a* associated with the video content **220**. The second encoding module **206** is configured to compress the second slice **222***b* to form a second independently compressed video slice **224***b* associated with the video content **220**. The first and second independently compressed video slices **224***a* and **224***b* are not necessarily compressed with reference to other video streams, for instance, in contrast to MVC coded video streams in which the video streams are coded with respect to each other. Instead, each of the first encoding module **204** and the second encoding module **206** may respectively compress the first independently compressed video slice **224***a* and the second independently compressed video slice **224***b* without referencing the other one of the video slices **224***a* and **224***b*. "MPEG," as used herein, refers to a group of standards for encoding and decoding transport streams as defined by the Moving Picture Experts Group. MPEG includes several formats for transport streams such as MPEG-2 and MPEG-4 part **10**/H.264. At least by virtue of the fact that the video contained in the first slice **222***a* and the second slice **222***b* are compressed separately, either of the first independently compressed video slice **224***a* and the second independently compressed video slice **224***b* may be decoded for viewing in 2D format.

According to an embodiment, the first independently compressed video slice **224***a* is compressed using a first compression format, for instance MPEG-2 and the second independently compressed video slice **224***b* is compressed using a second compression format, which differs from the first compression format, for instance MPEG-4. When the two slices **222***a*-**222***b* are compressed using different coding standards (e.g. MPEG-2 and MPEG-4) the broadcast-centric constraints allow two video components with different stream_type values within same program (that is, the existing stream_type values for MPEG-2 video (0×02) and MPEG-4 (0×1B) may be used).

According to another embodiment, the first and second independently compressed video slices **224***a* and **224***b* are compressed in a common compression format. The second independently compressed video slice **224***b* may be at a lower resolution than the first independently compressed video slice **224***a*. The second independently compressed video slice **224***b* is assigned a new stream type that is different than the first independently compressed video slice **224***a* in the program map table for the transport stream **131**. A program map table is used to describe each single program including elementary streams associated with the program. The stream type may be specified in the program map table. The new stream type for the second view may be allocated by a transport system, for instance MPEG-2

As further shown in FIG. **2**, the descriptor processing module **208** is configured to receive the first independently compressed video slice **224***a* and the second independently compressed video slice **224***b* from the first encoding module **204** and the second encoding module **206**. The descriptor processing module **208** is also configured to create and add an associated descriptor **226** to the first and second independently compressed video slices **224***a* and **224***b*. The descriptor **226** may comprise information pertaining to, for instance, which view each of the first and second independently compressed video slices **224***a* and **224***b* pertains, which encoding standard(s) was implemented to encode each of the first and second independently compressed video slices **224***a* and **224***b*, upsampling rules in instances where view resolutions differ, information for combining the views (for instance, field interleaving or frame interleaving, etc. The descriptor processing module **208** may receive information describing the first and second independently compressed video slices **224***a* and **224***b* from one or more of the manipulating module **202**, the first encoding module **204** and the second encoding module **206**, and may use this information in generating the descriptor **226**. The descriptor **226** is configured to allow a decoder that receives the transport stream **131** containing the compressed video slices **224***a* and **224***b* to decode (including any adjustment of video resolutions) and render a 2D or 3D video from the decoded first and second slices **222***a* and **222***b*.

The multiplexing module **210** is configured to receive the first and second independently compressed video slices **224***a* and **224***b* respectively from the first encoding module **204** and the second encoding module **206**. The multiplexing module **210** is thereafter configured to multiplex the first and second independently compressed video slices **224***a* and **224***b* along with the associated descriptor **226** to form at least one transport stream **131**. For example, the first and second independently compressed video slices **224***a* and **224***b* may be included in a single transport stream. Alternately, the independently compressed video slices **224***a* and **224***b* may be sent in separate transport streams. The independently compressed video slices **224***a* and **224***b* and the descriptor **226** may be included in a common program in the at least one transport stream **131**. A common program may correspond, for instance, to a single broadcasted channel. In addition, or alternatively, the at least one transport stream **131** may comprise Internet Protocol (IP) packets or may conform to any packetization scheme configured to enable transmission of the transport stream **131**. For instance, the transport stream **131** may comprise an MPEG stream, IP packets or any suitable medium for transporting the 3D video from a source to an end user.

FIG. **3** illustrates an alternative implementation of a 3D video encoder **260**, according to an embodiment. As shown in FIG. **3**, the 3D video encoder **260** includes a view merger **264**, a frame slicer **266**, an encoder **268**, and a stream separator **270**. It should be understood that the 3D video encoder **260** depicted in FIG. **3** may include additional components and that some of the components described herein may be removed and/or modified without departing from a scope of the 3D video encoder **260**.

As shown in FIG. **3**, the view merger **264** receives bits associated with a left view **262***a* and bits associated with a right view **262***b*. The view merger **264** is configured to merge the left and right views **262***a*-**262***b* to form a single frame, for instance in a top and bottom format. In addition, the view merger **264** is configured to associate a descriptor for 3D composition with the single frame. The descriptor for 3D composition is configured to allow a decoder that receives at least one transport stream from the encoder **260** to decode (including any adjustment of video resolutions) and render a 2D or 3D video from the bits of the decoded first and second views **262***a* and **262***b* The frame slicer **266** is configured to slice the single frame into a plurality of slices of video for transport, for instance, as part of the same transport stream.

The encoder with deblocking filter control **268** is configured to encode the slices of video to form a single video frame and bit stream or alternately two separate bit streams. According to an embodiment, the single video frame and bit stream may be sent to end users, for instance, the subscribers **150***a*-**150***n* in FIG. **1**. Alternately, the single stream video frame may be separated by the stream separator **270** to form first and second independently compressed video slices **224***a*-**224***b* and and communicated as separate video slices in multiple transport streams, for instance, as shown in and discussed with respect to FIG. **2** hereinabove.

FIG. **4** illustrates a simplified block diagram of a system **300** configured to receive and display 3D content, according to an embodiment. The system **300** is depicted as including the STB **120***c*, including the 3D decoder **130**, and the 3D-ready TV **122** from FIG. **1**. As discussed above, the functions of the STB **120***c* may be performed by a variety of other devices, such as, devices and/or software integrated into one or more of televisions, computers, cellular telephones, PDAs, etc. It should be understood that the system **300** depicted in FIG. **4** may include additional components and that some of the components described herein may be removed and/or modified without departing from a scope of the system **300**.

As shown in FIG. **4**, the STB **120***c* includes an input/output module **302**, a demultiplexing module **304**, and the 3D video decoder **130**, which includes a 3D decoding module **306**, and a 3D combining module **308**. The modules **302**-**308** may comprise software, hardware, or a combination of software and hardware. Thus, in one embodiment, one or more of the modules **302**-**308** comprise circuit components. In another embodiment, one or more of the modules **302**-**308** comprise software code stored on a computer readable storage medium, which is executable by a processor.

The input/output module **302** is configured to receive the transport stream **131** from the head end **110**. The input/output module **302** may comprise a Universal Serial Bus (USB), an Ethernet interface, or another type of interface and the transport stream **131** may be a QAM modulated stream.

The demultiplexing module **304** may thereafter select a frequency and demodulate the frequency to obtain a multi program transport stream (MPTS). The demultiplexing module **304** is configured to demultiplex the MPTS to extract single program transport streams (SPTSs) corresponding to each of a plurality of programs which a subscriber may select. For instance, the subscriber **150***n* may use the STB **120***c* to select a program having 3D content. The demultiplexing module **304** then demultiplexes the MPTS to form the first and second independently compressed video slices **224***a* and **224***b*. Each of the first and second independently compressed video slices **224***a* and **224***b* has a different codec.

The 3D decoding module **306** is configured to decode the first and second independently compressed video slices **224***a* and **224***b* to form a first view and a second view. In decoding the first and second independently compressed video slices **224***a* and **224***b*, the 3D decoding module **306** is configured to access the descriptor **226** in the transport stream **131** and to employ the instructions contained therein in decoding the compressed video slices **224***a* and **224***b*.

The 3D rendering module **308** is configured to access the descriptor **226** in the transport stream **131** and render the 3D video **310** using the instructions contained therein. More particularly, the 3D rendering module **308** is configured to process the decoded first and second independently compressed video slices **224***a* and **224***b* to form the 3D video **310** suitable for display on the 3D-ready TV **122** as stereoscopic or multiple views. The descriptor **226** may include supplemental enhancement information (SEI) to form the 3D video **310**. In addition, the input/output module **302** is configured to thereafter output the 3D video **310**, for instance to a 3D-ready TV.

According to an embodiment, the first and second independently compressed video slices **224***a* and **224***b* are received in a single frame in a single transport stream. Alternately, the bits for the first and second independently compressed video slices **224***a* and **224***b* may be received in separate transport streams.

According to another embodiment, in instances in which the at least one transport stream **131** is an MPEG-2 conformant stream, some of the rendering and combining information from the descriptor **226** may be included in the compressed video stream (such as picture user-data). This provides information on use of single stream, combining and rendering two fields or two frames in the same video sequence and additional display related elements.

According to another embodiment, the 3D rendering module **308** is configured to stitch the frames (each of half vertical resolution) corresponding to the first and second views into a single video frame with the top half comprising one eye view and the bottom half comprising the other eye view. The 3D rendering module **308** is further configured to create a video frame in a top and bottom panel format and sends the video frame to a 3D ready TV **122** that is configured to render 3D video in the top and bottom panel format. The 3D video decoder **130** or the STB **120***c* may also be configured to insert caption text and on-screen display (OSD) information in both halves of the 3D video in the top and bottom panel format.

According to another embodiment, to render the 3D video **310**, the 3D rendering module **308** is configured to vertically interpolate frames corresponding to both eye views to full resolution and to output the vertically interpolated frames to the 3D-ready TV **122** for 3D display. Additionally, the STB **120***c* may also be configured to insert caption text and OSD information in both of the vertically interpolated frames.

According to a further embodiment in which an STB **120***n* includes a 2D decoder **121**, the 2D decoder **121** is able to render a 2D video from the same transport stream **131** containing both the first and second compressed video slices **224***a* and **224***b*. In this regard, the 2D decoder **121** is configured to decode one of the first and second compressed video slices **224***a* and **224***b* and to render of decoded streams for display on a 2D or 3D display. The 2D decoder **121** is capable of rendering a full resolution 2D video stream from one of the first and second compressed video slices **224***a* and **224***b* because each of the first and second compressed video slices **224***a* and **224***b* were compressed independently of each other. In addition, the 2D decoder **121** may interpolate one of the first view and the second view vertically to full resolution for display at a 2D or 3D display. Moreover, the 2D decoder **121** may discard the view that is not used to generate the video to be displayed. Accordingly, the transport stream **131** may be used to provide backwards compatibility in a network architecture having a mixture of STBs with conventional 2D decoders and STBs with 3D decoders. Additionally, the STB **120***n* in which the conventional 2D decoder is installed, for instance a conventional set top box, may be configured to insert caption text and OSD information after the interpolation.

According to an example, the 2D decoder **121** may select one of the first and second compressed video slices **224***a* and **224***b* based upon the type of compression employing to encode the video slices **224***a* and **224***b*. By way of example in which the 2D decoder **121** is configured to decode MPEG-2 encoded streams and the first compressed video slice **224***a* has been compressed using the MPEG-4 standard and the second compressed video slice **224***b* has been compressed using being MPEG-2 standard, the 2D decoder **121** may be configured to decode the second compressed video slice **224***b*.

Examples of a method in which the 3D video encoder **200** and the STB **120***c* may be employed for encoding a video stream and a method in which the video stream may be decoded to render video for display are now described with respect to the following flow diagrams of the methods **400** and **500** depicted in FIGS. **5** and **6**, respectively. It should be apparent to those of ordinary skill in the art that the methods **400** and **500** represent generalized illustrations and that other steps may be added or existing steps may be removed, modified or rearranged without departing from the scopes of the methods **400** and **500**. In addition, the methods **400** and **500** are described with respect to the components depicted in FIGS. **2**, **3**, and **4** by way of example and not of limitation.

Some or all of the operations set forth in the methods **400** and **500** may be contained as one or more computer programs stored in any desired computer readable medium and executed by a processor on a computer system. Exemplary computer readable media that may be used to store software operable to implement the present invention include but are not limited to conventional computer system RAM, ROM, EPROM, EEPROM, hard disks, or other data storage devices.

With reference first to FIG. **5**, there is shown a method **400** of encoding video content **220** to form a transport stream **131**, according to an embodiment. The method **400** may be performed by the 3D video encoder **200** as described with respect to FIG. **2** hereinabove.

At step **402**, video content **220** is accessed, for instance, by the manipulating module **202**. As discussed above, the video content **220** may include a first view and a second view. The first view and the second view, may be operable to render 3D video.

At step **404**, the manipulating module **202** manipulates the first and second views to occupy separate slices of video **800**. For instance, the first and second views may be manipulated to occupy a first slice **222***a* of video and a second slice **222***b* of video, as shown in FIG. **8**.

At step **406**, the separate slices of video **800** are encoded by, respectively, the first encoding module **204** and the second encoding module **206** to form a first independently compressed video slice **224***a* and a second independently compressed video slice **224***b*. The first and second independently compressed video slices **224***a* and **224***b* may be compressed in a common compression format or alternately, in different compression formats as described hereinabove with respect to FIG. **2**.

At step **408**, the descriptor processing module **208** generates a descriptor **226** containing information for use in decoding and combining the first and second independently compressed video slices **224***a* and **224***b* to form one or both of a 2D and a 3D video.

At step **410**, the multiplexing module **210** multiplexes the first and second independently compressed video slices **224***a* and **224***b* to form at least one transport stream **131**. A decoder that receives the at least one transport stream **131** may be configured to decode the compressed video slices **224***a* and **224** contained in the at least one transport stream **131** to render a 2D or 3D video. The multiplexing module **210** may also include the descriptor **226** in the at least one transport stream **131**.

At step **412**, the transport stream **131** is output over a network to one or more subscribers **150***a*-**150***n*, for instance as shown in FIG. **1**.

Turning now to FIG. **6**, there is shown a method **500** of rendering at least one transport stream **131** into a 2D or 3D displayable video, according to an embodiment. The method **500** may be performed by the STB **120***c* and/or the STB **120***n* as described with respect to FIG. **4** hereinabove.

At step **502**, at least one transport stream **131** is received through, for instance, the input/output module **302** of the STB **120***c*/**120***n*. As discussed above, the at least one transport stream **131** includes the first and second independently compressed video slices **224***a* and **224***b* as well as the descriptor **226**.

At step **504**, at least one of the first and second independently compressed video slices **224***a* and **224***b* is decoded. In a first example in which the decoder comprises a 3D decoder **130**, the 3D decoder **130** decodes both the first and second independently compressed video slices **224***a* and **224***b* for rendering into a 3D display format. In a second example in which the decoder comprises a 2D decoder **121**, the 2D decoder **121** becomes one of the first and second independently compressed video slices **224***a* and **224***b* for rendering into a 2D display format.

At step **506**, the at least one decoded video slice is rendered for display as one of a 2D and a 3D video, for instance, by the 3D rendering module **308**. In addition, at step **508**, the rendered 2D or 3D video is output to one of a 2D and a 3D display **122** and **123**.

Turning now to FIG. **7**, there is shown a schematic representation of a computing device **600** configured in accordance with embodiments of the present invention. The computing device **600** includes one or more processors **602**, such as a central processing unit; one or more display devices **604**, such as a monitor; one or more network interfaces **608**, such as a Local Area Network LAN, a wireless 802.11x LAN, a 3G mobile WAN or a WiMax WAN; and one or more computer-readable mediums **610**. Each of these components is operatively coupled to one or more buses **612**. For example, the bus **612** may be an EISA, a PCI, a USB, a FireWire, a NuBus, or a PDS.

The computer readable medium **610** may be any suitable medium that participates in providing instructions to the processor **602** for execution. For example, the computer readable medium **610** may be non-volatile media, such as an optical or a magnetic disk; volatile media, such as memory; and transmission media, such as coaxial cables, copper wire, and fiber optics. Transmission media can also take the form of acoustic, light, or radio frequency waves. The computer readable medium **610** may also store other software applications, including word processors, browsers, email, Instant Messaging, media players, and telephony software.

The computer-readable medium **610** may also store an operating system **614**, such as Mac OS, MS Windows, Unix, or Linux; network applications **616**; and a video encoding/decoding application **618**. The operating system **614** may be multi-user, multiprocessing, multitasking, multithreading, real-time and the like. The operating system **614** may also perform basic tasks such as recognizing input from input devices, such as a keyboard or a keypad; sending output to the display **604**; keeping track of files and directories on medium **610**; controlling peripheral devices, such as disk drives, printers, image capture device; and managing traffic on the one or more buses **612**. The network applications **616** include various components for establishing and maintaining network connections, such as software for implementing communication protocols including TCP/IP, HTTP, Ethernet, USB, and FireWire.

The video encoding/decoding application **618** provides various software components for at least one of encoding 3D video content for transmission in a transport stream and decoding encoded video content for display as a 2D or 3D video, as discussed above. In certain embodiments, some or all of the processes performed by the application **618** may be integrated into the operating system **614**. In certain embodiments, the processes can be at least partially implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in any combination thereof, as also discussed above.

Embodiments of the present invention provide a method and apparatus for encoding video content to be rendered by a decoder as one of a 2D and a 3D video. The video content includes first and second views that correspond to displays for left and right eyes. When the video content is to be displayed as a 3D video, both the first views and second views are rendered. However, when the video content is to be displayed as a 2D video, such as, when a set-top box is equipped with a 2D decoder, only one of the first view and the second view is rendered. As such, a single transport stream containing both the first view and the second view may be transmitted to set-top boxes having one of a 2D and a 3D decoder.

What has been described and illustrated herein are embodiments of the invention along with some of their variations. The terms, descriptions and figures used herein are set forth by way of illustration only and are not meant as limitations. Those skilled in the art will recognize that many variations are possible within the spirit and scope of the invention, wherein the invention is intended to be defined by the following claims—and their equivalents—in which all terms are meant in their broadest reasonable sense unless otherwise indicated.

What is claimed is:

1. A method of encoding video content, the method comprising:

manipulating bits of a first view and a second view of a three-dimensional (3D) video content to occupy a first slice of video and a second slice of video, the first view being a left eye view of the three-dimensional (3D) video content, the second view being a right eye view of the three-dimensional (3D) video content, wherein a boundary is formed between the first slice of the first view of the three-dimensional (3D) video content and the second slice of the second view of the three-dimensional (3D) video content, wherein the boundary enables a deblocking filter to be turned off across the boundary to prevent cross-talk between the left eve view of the first slice and the right eye view of the second slice, the deblocking filter being activated within each of the left eye view of the first slice and the right eye view of the second slice;

encoding the bits of each of the left eve view of the first slice and the right eve view of the second slice separately from each other to form a first independently compressed video slice and a second independently compressed video slice; and

multiplexing the first and second independently compressed video slices to form at least one transport stream, wherein the at least one transport stream is operable to be processed to render at least one of a two-dimensional (2D) video and a 3D video.

2. The method of claim **1**, wherein multiplexing the first and second independently compressed video slices to form the at least one transport stream further comprises:

multiplexing the first and second independently compressed video slices to form a single video frame, wherein the at least one transport stream includes the single video frame.

3. The method of claim **1**, wherein multiplexing the first and second independently compressed video slices to form the at least one transport stream further comprises:

multiplexing the first and second independently compressed video slices to form separate video slices, wherein the at least one transport stream includes the separate video slices.

4. The method of claim **1**, wherein encoding each of the first slice and the second slice separately from each other further comprises:

encoding the bits of the first slice and the second slice in a common compression format and assigning different stream types to the first independently compressed video slice and the second independently compressed video slice.

5. The method of claim **1**, wherein the first independently compressed video slice is compressed using a first compression format, and the second independently compressed video slice is compressed using a second compression format, wherein the first compression format is different than the second compression format.

6. The method of claim **1**, wherein at least one of the first and second independently compressed video slices is encoded in a full resolution 2D compatible stream operable to be processed to display the 2D video.

7. The method of claim **1**, further comprising:

generating a descriptor, wherein the descriptor contains information for use in rendering at least one of the first and second independently compressed video slices to render the at least one of the 2D video and the 3D video; and

wherein multiplexing the first independently compressed video slice and the second independently compressed video slice further comprises including the descriptor in the at least one transport stream.

8. A method of rendering at least one transport stream into a displayable video, the method comprising:

receiving the at least one transport stream, said transport stream including a first independently compressed video slice corresponding to a first view of a three-dimensional (3D) video content and a second independently compressed video slice corresponding to a second view of the three-dimensional (3D) video content, the first view being a left eye view of the three-dimensional (3D) video content, the second view being a right eye view of the three-dimensional (3D) video content, wherein the first and second views are configured to occupy separate slices of video, and wherein a boundary is formed between the left eve view of the first slice of the first view of the three-dimensional (3D) video content and the right eve view the second slice of the second view of the three-dimensional (3D) video content, wherein the boundary enables a deblocking filter to be turned off across the boundary to prevent crosstalk between the left eve view of the first slice and the right eve view of the second slice, the deblocking filter being activated within each of the left eve view of the first slice and the right eye view of the second slice;

decoding bits of at least one of the first and second independently compressed video slices; and

rendering one of a two-dimensional (2D) video and a 3D video using the at least one decoded first and second independently compressed video slices.

9. The method of claim **8**, wherein the first and second independently compressed video slices are received as one of a single video frame and separate video slices.

10. The method of claim **8**, wherein receiving the at least one transport stream further comprises:

receiving a descriptor in the at least one transport stream; and

wherein at least one of decoding and rendering further comprises at least one of decoding and rendering using the descriptor.

11. The method of claim **8**, wherein the bits of the first and second independently compressed video slices have been respectively encoded in first and second compression formats that are different from each other, said method further comprising:

determining compression formats of the first and second independently compressed video slices;

selecting one of the first and second independently compressed video slices that has been compressed using a compression format compatible with a decoder; and

wherein decoding further comprises decoding the bits of one of the first and second independently compressed video slices that has been compressed using a compatible compression format to render the 2D video.

12. The method of claim **8**, wherein rendering the one of the 2D and the 3D video further comprises:

combining frames corresponding to the first and second slices into a single video frame, wherein the single video frame includes a top half composed of the bits of the first view and a bottom half composed of the bits of the second view.

13. A video encoder for encoding video content, the video encoder comprising:

one or more modules configured to manipulate bits of a first view and a second view of a three-dimensional (3D) video content to occupy a first slice of video and a second slice of video, the first view being a left eye view of the three-dimensional (3D) video content, the second view being a right eye view of the three-dimensional (3D) video content, wherein a boundary is formed between the left eve view of the first slice of the first view of the three-dimensional (3D) video content and the right eye view of the second slice of the second view of the three-dimensional (3D) video content, wherein the boundary enables a deblocking filter to be turned off across the boundary to prevent crosstalk between the left eve view of the first slice and the right eve view of the second slice, the deblocking filter being activated within each of the left eve view of the first slice and the right eye view of the second slice,

the one or more modules configured to encode the bits of each of the first and the second slices separately from each other to form a first independently compressed video slice and a second independently compressed video slice, and to multiplex the first independently compressed video slice and the second independently compressed video slice to form at least one transport stream, wherein the at least one transport stream is operable to be processed to render at least one of a two-dimensional (2D) video and a 3D video; and

a processor configured to implement the one or more modules.

14. The video encoder of claim **13**, wherein the one or more modules are further configured to multiplex the bits of the first and second independently compressed video slices to form one of a single video frame and separate video slices.

15. The video encoder of claim **13**, wherein the one or more modules are further configured to encode the bits of the first slice and the second slice under a common compression format and to assign the first and second independently compressed video slices with different stream types.

16. The video encoder of claim **15**, wherein the one or more modules are further configured to encode the bits of the first slice and the second slice to be processed by a 2D decoder to form a full resolution 2D compatible stream.

17. The video encoder of claim **13**, wherein the one or more modules are further configured to generate a descriptor associated with the first and second independently compressed video slices, wherein the descriptor contains information for use in rendering the bits of at least one of the first and second independently compressed video slices to render the at least one of the 2D video and the 3D video and to include the descriptor in the at least one transport stream.

18. A video decoder comprising:

one or more modules configured to receive at least one transport stream including a first independently compressed video slice corresponding to a first view of a three-dimensional (3D) video content and a second independently compressed video slice corresponding to a second view of the three-dimensional (3D) video content, the first view being a left eye view of the three-dimensional (3D) video content, the second view being a right eye view of the three-dimensional (3D) video content, wherein the first and second views are configured to occupy separate slices of video, and wherein a boundary is formed between the left eye view of the first slice of the first view of the three-dimensional (3D) video content and the right eye view of the second slice of the second view of the three-dimensional (3D) video content, wherein the boundary enables a deblocking filter to be turned off across the boundary to prevent crosstalk between the left eye view of the first slice and the right eye view of the second slice, the deblocking filter being activated within each of the left eye view of the first slice and the right eye view of the second slice;

said one or more modules being further configured to decode bits of one of the first and second independently compressed video slices when rendering two-dimensional (2D) video and decode bits of both the first and second independently compressed video slices when rendering 3D video; and

a processor configured to implement the one or more modules.

19. The video decoder of claim **18**, wherein the one or more modules are further configured to determine compression formats of the first and second independently compressed video slices, to select one of the first and second independently compressed video slices that has been compressed using a compression format compatible with a decoding module, and to decode the bits of one of the first and second independently compressed video slices that has been compressed using a compatible compression format to render a 2D video.

20. The method of claim **1**, wherein the boundary defines a physical region to be provided for separating images on a video display.

21. The method of claim **20**, wherein the boundary separates a top and a bottom of the video display.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,432,723 B2
APPLICATION NO. : 12/849308
DATED : August 30, 2016
INVENTOR(S) : Luthra

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Claims

In Column 11, Line 60, Claim 1, delete "eve" and insert -- eye --, therefor.

In Column 11, Line 65, Claim 1, delete "eve" and insert -- eye --, therefor.

In Column 11, Line 66, Claim 1, delete "eve" and insert -- eye --, therefor.

In Column 12, Line 63, Claim 8, delete "eve" and insert -- eye --, therefor.

In Column 12, Line 65, Claim 8, delete "eve" and insert -- eye --, therefor.

In Column 13, Line 2, Claim 8, delete "eve" and insert -- eye --, therefor.

In Column 13, Line 3, Claim 8, delete "eve" and insert -- eye --, therefor.

In Column 13, Line 4, Claim 8, delete "eve" and insert -- eye --, therefor.

In Column 13, Line 51, Claim 13, delete "eve" and insert -- eye --, therefor.

In Column 13, Line 57, Claim 13, delete "eve" and insert -- eye --, therefor.

In Column 13, Line 58, Claim 13, delete "eve" and insert -- eye --, therefor.

In Column 13, Line 59, Claim 13, delete "eve" and insert -- eye --, therefor.

Signed and Sealed this
Eighth Day of November, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office